Mu2e Notes: Theory

Tuesday, February 16, 2010
10:55 AM

- The Goals
  - Charted Lepton Flavor Violation (CLFV)
  - Neutrino-less conversion of muon to electron
    - μ^- + (A,Z) → e^- + (A,Z)
  - Ordinary Muon Caputre
    - μ^- + (A,Z) → ν_μ + (A,Z-1)
  - Ratio

$$R = \frac{\mu^- + (A,Z) \rightarrow e^- + (A,Z)}{\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z\text{-}1)}$$

    - Goals
      - Stage I: R < 6 x 10^{-17} (Al, 90% c.l.)
      - Stage II: R < 10^{-18}
- The method
  - Protons → low energy pions → low energy muons → stop in target → Muonic atom formed
  - Bohr Radius (1s) must less than 1s orbit of innermost atomic electrons
    - $r_B = \frac{a_0 m_e}{Z m_\mu}$
  - Bohr Energy (1s) is ~470KeV for Al
    - $E_B = (13.6eV)Z^2 \frac{m_\mu}{m_e}$
  - There are three possible interactions:
    - Muon to electron conversion.
      - μ^- + (A,Z) → e^- + (A,Z)
      - Here the conversion electron (ce) is monoenergetic
        - $E_{ce}(Al) = 105.0MeV$
    - Muon decay
      - μ^- + (A,Z) → e- + ν_μ + ν_e+ (A,Z)
      - Here the endpoint of bound muon is the same as the conversion energy (can transfer some energy to the nucleus).
        - $E_e(\max) = E_{ce}(Al) = 105.0MeV$
    - Muon capture on nucleus
      - μ^- + p → ν_μ + n
      - μ^- + (A,Z) → ν_μ + (A',Z')+ protons + neutrons + γ's
  - Muonic aluminum properties
    - Muon lifetime = 0.86 μSec
    - Partial decay lifetime = 2.2 μSec
    - Partial capture lifetime = 1.5 μSec
- Potential Backgrounds
  - Electrons from decay of muon bound atomic orbit
    - Max. energy is the same as the conversion electron energy
    - Probability falls quickly near endpoint
    - Background can be separated from conversion electrons with good electron energy resolution.

        - < 1 MeV FWHM for Mu2e R < 6 x 10^{17}.
    - Vast majority of decay electrons are < 53 MeV.
    - Delayed background
- Prompt background
    - Radiative pion capture, followed by photon conversion. E up to 140MeV.
        - $\pi^- + (A,Z) \rightarrow (A,Z-1) + \gamma$
- Flow of low energy protons, neutrons, gammas from ordinary muon capture on stopping target nuclei- can lead to tracking errors
- Beam electrons ~ 105MeV
- Cosmic rays- suppress with shielding and 4π veto.